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Prioritizing selection of new elements: On the time course of the preview effect

Mieke Donk

*Department of Cognitive Psychology, Vrije Universiteit, Amsterdam,
The Netherlands*

The preview effect demonstrates that if observers in a visual search task are allowed a preview of a subset of elements before another subset of new elements is added, the first subset of elements does no longer compete for attentional selection. The aim of the present study was to investigate how long after the presentation of the new elements the preview effect can be preserved. Observers were presented with displays containing one set of elements (old elements) followed after a certain time interval by a second set of elements (new elements). Observers searched for the presence of a target among the new elements. The target appeared through an equiluminant colour change at varying intervals after the presentation of the new elements. The results indicated that the preview effect disappears beyond 200 ms after the presentation of the new elements. The results are discussed in terms of visual marking, temporal segregation, and onset capture.

In everyday life, we are confronted with an enormous amount of visual information. Yet, our information processing capacity is limited. To behave efficiently, the visual system must select only that information that is relevant to the behavioural goals. That is, the visual system must attend to relevant and ignore irrelevant stimuli. A major question within the area of visual attention is how the observer manages to do so well in this respect. How does the visual system prioritize relevant information over irrelevant information? What information can be used to guide attentional selection and what is the mechanism underlying this attentional guidance?

One likely candidate in the guidance of visual attention might be related to “newness” (e.g., Donk & Theeuwes, 2001; Jonides & Yantis, 1988; Theeuwes, 1991, 1994; Watson & Humphreys, 1997; Yantis & Hillstrom, 1994; Yantis &

Please address all correspondence to: Mieke Donk, Department of Cognitive Psychology, Vrije Universiteit, van der Boechorststraat 1, 1081 BT Amsterdam, The Netherlands.

Email: w.donk@psy.vu.nl

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Johnson, 1990; Yantis & Jones, 1991; Yantis & Jonides, 1984, 1990). In monitoring the visual environment, new information is very often more important than information already present. Accordingly, various researchers have proposed that observers may have a mechanism at their disposal that enables them to prioritize the selection of new over old objects. Evidence for the existence of such a mechanism derives from experiments utilizing the *preview paradigm* introduced by Watson and Humphreys (1997). In this paradigm, a set of elements (old elements) appears at least 400 ms before the presentation of another set of elements (new elements). Observers have the task to search for the presence of a target that can only appear among the new elements. Search performance in this preview condition is compared to that in a condition in which all elements are presented simultaneously and a condition in which only the new elements are presented. The important finding is the so-called preview benefit that shows that search in the preview condition is much more efficient than that obtained in the condition in which all elements are presented simultaneously. In fact, observers are able to selectively ignore the old elements in that search efficiency in the preview condition is equal to that in the condition in which only the new elements are presented. Even though these results indicate that observers are able to selectively assign priority to processing new elements, it is still a matter of debate how this prioritizing is exactly accomplished (see Donk & Theeuwes, 2001, 2003; Donk & Verburg, 2004; Jiang, Chun, & Marks, 2002; Watson & Humphreys, 1997).

Originally, Watson and Humphreys (1997) proposed that prioritized selection of new over old elements occurs because observers selectively inhibit the locations occupied by the old elements, a process they referred to as visual marking. The mechanism by which new objects are prioritized over old ones is assumed to operate through the inhibition of the locations of the old elements (Humphreys, Jung-Stalmann, & Olivers, 2004; Kunar, Humphreys, Smith, & Watson, 2003c; Watson and Humphreys, 1997, 2000) or the inhibition of whole feature maps (Braithwaite, & Humphreys, 2003; Braithwaite, Humphreys, & Hodsoll, 2003; Kunar, Humphreys, & Smith, 2003a; Olivers & Humphreys, 2002, 2003; Olivers, Watson, & Humphreys, 1999; Watson, 2001; Watson & Humphreys, 1998, 1999). That is, new elements may receive prioritized attentional selection because old elements can be voluntarily deprioritized prior to the presentation of the new elements. As a consequence, old elements do not compete for attentional processing when new elements appear.

Alternatively, Jiang et al. (2002) proposed that (part of) the preview effect might be the result of the ability of observers to group subsets of elements on the basis of their temporal separation. According to their temporal segregation hypothesis, the preview effect occurs because segregation of old and new elements allows attention to be selectively deployed to the group that contains the target. Even though the temporal segregation hypothesis differs from the visual marking hypothesis in some aspects (see Jiang et al., 2002; Kunar, Humphreys,

& Smith, 2003b), both accounts share the idea that prioritized selection is the result of top-down processing. That is, according to both views, observers are assumed to voluntarily prioritize the selection of new over old elements.

A completely different view was proposed by Donk and Theeuwes (2001; see also Belopolsky, Theeuwes, & Kramer, in press; Donk & Theeuwes, 2003; Donk & Verburg, 2004). They argued that prioritized selection of new over old elements is mediated by a bottom-up process that is based on attentional capture by the onsets accompanying the appearance of the new elements.¹ It is assumed that observers are not actively involved with inhibition or segregation. Instead, prioritized selection is assumed to be the result of a passive process occurring instantaneously upon the presentation of the new elements.

Even though the alternative theoretical notions put forward to account for the preview benefit are very different, they are not mutually exclusive. That is, it is feasible that observers simultaneously use multiple mechanisms to prioritize selection of new over old elements. For example, it is possible that through visual marking, observers are able to enhance the power of luminance onsets to capture attention (but see Donk & Theeuwes, 2003; Donk & Verburg, 2004). Alternatively, observers may be simultaneously involved with one process segregating old from new elements and another process that inhibits old elements during the preview (Jiang et al., 2002).

The aim of the present study is to contribute to the understanding of how observers prioritize selection of new over old elements by analysing the time course of the preview benefit as a function of the time elapsed *after* the new elements have been presented. To investigate the time course of the preview benefit, an experiment was conducted in which the interval was manipulated between the presentation of the new elements and the target. Observers performed a preview task, yet, instead of being able to start searching immediately after the presentation of the second set of elements, participants had to wait for a tone indicating the moment of possible target presentation. The tone was presented at 0 ms, 50 ms, 100 ms, 200 ms, or 400 ms after the presentation of the new elements. Concurrently with the presentation of the tone, the target appeared in 50% of the trials through an equiluminant colour change of one of the new elements. Number of old elements and number of new elements were independently varied (see, for a similar procedure, Donk & Theeuwes, 2001; Theeuwes, Kramer, & Atchley, 1998).

¹ The term “onset” is used to refer to the “presentation of a stimulus accompanied by a luminance increment”.

METHOD

Participants

Eight male and 12 female participants aged 17–44 years took part in the present experiment. Each participant had normal or corrected-to-normal vision.

Apparatus

A Celeron 400 MHz/128 Mb PC controlled the timing of events, the generation of the stimuli, and the recording of the responses. Stimuli were presented on a 19-inch Multiscan colour monitor (with a ATI Rage 4 Mb-card). The “z” key and the “/” key of the computer keyboard were utilized as response buttons. Participants were tested in a sound-isolated dimly lit room. They were seated on a distance of 95 cm from the computer monitor with their heads fixed in a head-chin rest.

Task and stimuli

Participants had to indicate the presence or absence of a blue H among a variable number of blue As and green Hs. In each trial, 6, 10, or 14 letters (old elements) were presented followed after 400 ms by the addition of another 6, 10, or 14 letters (new elements).² Both old and new elements always consisted of 50% As and 50% Hs. The target was presented in 50% of the trials. The moment of possible target presentation was indicated by the sound of a tone (1000 Hz, 200 ms), which occurred 0 ms, 50 ms, 100 ms, 200 ms, or 400 ms after the presentation of the new elements. In the target-present trials, concurrently with the presentation of the tone, one of the newly presented green Hs turned into blue. In the target-absent trials all elements remained unchanged at the screen. Blue and green were equiluminant as determined by a flicker fusion test (Ives, 1912) carried out at fixation (green: CIE x, y chromaticity coordinates of 0.253, 0.449, 6.5 cd/m²; blue: CIE x, y chromaticity coordinates of 0.164, 0.111, 6.2 cd/m²). The background was black with a luminance of 0.0 cd/m². The letters subtended a visual angle of $0.7^\circ \times 0.9^\circ$ at an observation distance of 95 cm and were randomly positioned within a stimulus field of $14.9^\circ \times 10.7^\circ$ of visual angle.

Design and procedure

A within-subjects design was used. Each participant completed two sessions each consisting of 1 block of 90 practice trials followed by 10 blocks of 90 experimental trials each. Altogether each participant completed 180 practice

² According to Watson and Humphreys (1997), a separation of 400 ms between the presentation of the old and new elements is sufficient to prioritize selection of new elements in the preview paradigm.

trials and 1800 experimental trials. Target presence (target present and target absent), number of old elements (6, 10, and 14 elements), number of new elements (6, 10, and 14 elements), and interval (0 ms, 50 ms, 100 ms, 200 ms, and 400 ms) were randomly varied within blocks of trials resulting in 20 trials per condition. Each trial started with the presentation of a white fixation cross in the middle of the screen. After 2000 ms, 6, 10, or 14 old elements were presented followed after 400 ms by the addition of 6, 10, or 14 new elements. After another 0 ms, 50 ms, 100 ms, 200 ms, or 400 ms, a tone was presented indicating the moment of possible target presentation. The display remained on until the participant responded with a maximum of 5000 ms after the presentation of the tone. The fixation cross remained on throughout each trial. Participants were instructed to remain fixated until the tone sounded and only start searching after the presentation of the tone. Furthermore, they were told that if the target would be present, it would appear among the new elements. Half of the participants pressed the "z" key when the target was present and pressed the "/" key when it was absent. This assignment was reversed for the other half of the participants. Participants received feedback about their performance in terms of reaction time (RT) and error rates after each block of 90 trials.

RESULTS

Reaction times (RT) longer than 2000 ms were counted as errors, which led to a loss of less than 0.2% of the trials. Figure 1 depicts the mean correct RTs as a function of target presence (target present and target absent), interval (0 ms, 50 ms, 100 ms, 200 ms, and 400 ms), the number of old elements (6, 10, or 14 elements), and the number of new elements (6, 10, or 14 elements). Overall, participants were faster to correctly respond to the presence of the target than to the absence of the target, $F(1, 19) = 27.36$, $p < .01$.

An ANOVA was conducted on the individual correct RTs of the target-present trials only with interval (0 ms, 50 ms, 100 ms, 200 ms, and 400 ms), the number of old elements (6, 10, or 14 elements), and the number of new elements (6, 10, or 14 elements) as repeated-measures factors. RT decreased with interval, $F(4, 76) = 3.56$, $p < .01$, and increased with the number of old elements, $F(2, 38) = 4.81$, $p < .01$, and the number of new elements, $F(2, 38) = 51.14$, $p < .01$. Furthermore, the effect of the number of old elements increased with interval, $F(8, 152) = 2.12$, $p < .04$, and the effect of the number of new elements decreased with interval, $F(8, 152) = 3.81$, $p < .01$. Finally, there was an interaction between the number of old elements and the number of new elements, $F(4, 76) = 3.17$, $p < .02$ indicating that the effect of the number of old elements increased as the number of new elements increased. There was no interaction between interval, number of old elements, and number of new elements, $F(16, 304) = 1.10$, $p > .05$. Separate analyses on the target-present trials per interval with the variables number of old elements and number of new elements

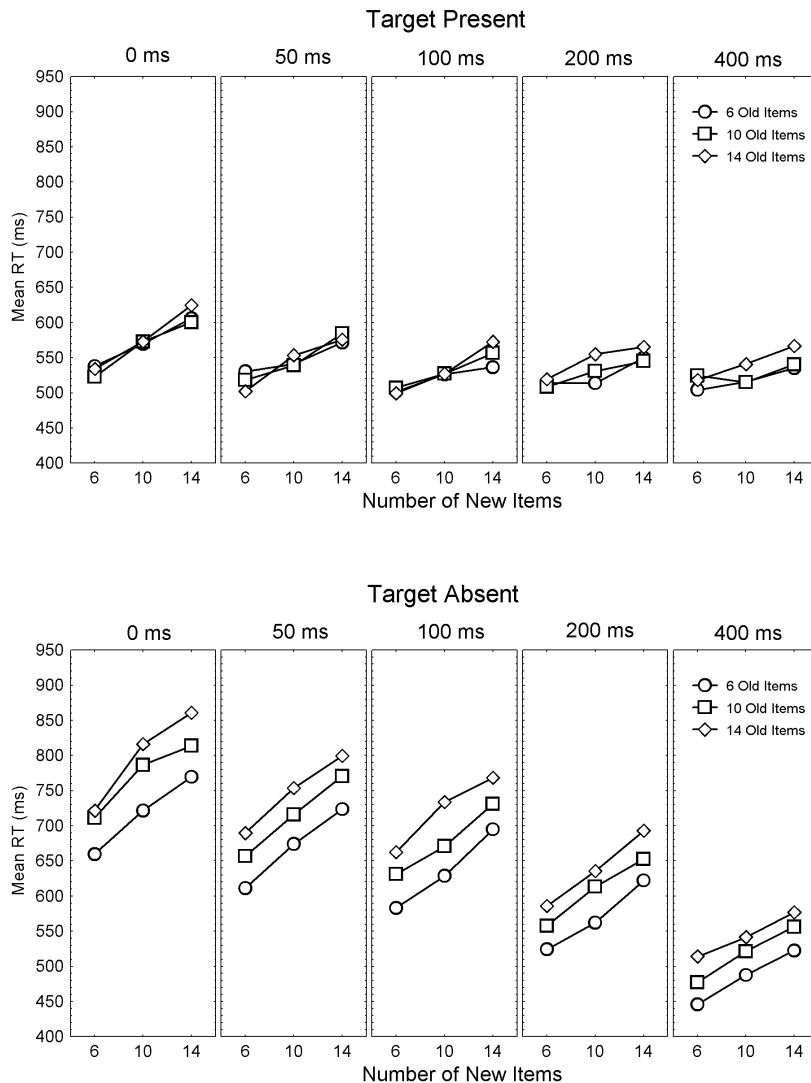


Figure 1. Correct mean RT as a function of the number of new elements and the number of old elements as a function of interval separately for target-present and target-absent trials.

showed that number of new elements always affected RT: Interval 0 ms, $F(2, 38) = 85.19$, $p < .01$; interval 50 ms, $F(2, 38) = 35.73$, $p < .01$; interval 100 ms, $F(2, 38) = 30.87$, $p < .01$; interval 200 ms, $F(2, 38) = 13.75$, $p < .01$; interval 400 ms, $F(2, 38) = 4.09$, $p < .02$, whereas number of old elements only affected RT with an interval of 200 ms and 400 ms: Interval 0 ms, $F(2, 38) = 2.99$, $p > .05$;

interval 50 ms, $F(2, 38) = 0.22$; interval 100 ms, $F(2, 38) = 1.73$, $p > .05$; interval 200 ms, $F(2, 38) = 3.64$, $p < .04$; interval 400 ms, $F(2, 38) = 5.81$, $p < .01$.

To investigate whether the speed of search was equal through the old elements and the new elements, best fitting lines were determined for the functions relating RT to the number of old elements and those relating RT to the number of new elements separately for each level of target presence and each level of interval for each participant (see also Donk & Theeuwes, 2001). Figure 2 shows the mean search slopes and Figure 3 shows the mean intercepts. Search slopes were larger for target-absent trials than for target-present trials, $F(1, 19) = 19.31$, $p < .01$. An analysis was performed on the slopes of the functions with the variables function (the function relating RT to the number of old elements and the function relating RT to the number of new elements) and interval (0 ms, 50 ms, 100 ms, 200 ms, and 400 ms) for the target-present trials only. The slopes of the functions relating RT to the number of old elements were smaller than those of the functions relating RT to the number of new elements, $F(1, 19) = 81.46$, $p < .01$. There was no main effect of interval, $F(4, 76) = 1.17$, $p > .05$, but the difference between the slopes of the functions relating RT to the number of old elements and those of the functions relating RT to the number of new elements decreased as interval increased, $F(4, 76) = 10.81$, $p < .01$: The slopes as a function of the number of old elements increased as a function of interval, $F(4, 76) = 3.63$, $p < .01$, whereas the slopes as a function of the number of new

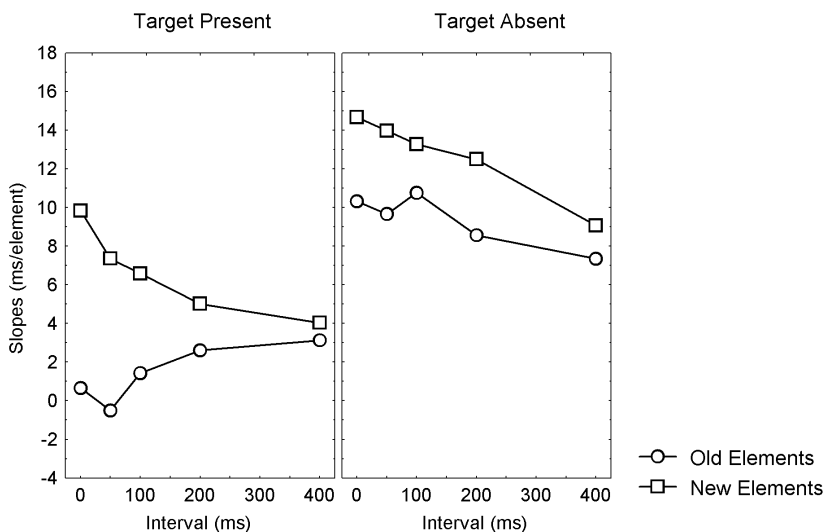


Figure 2. Mean search slopes of the functions relating RT to the number of old elements and of those relating RT to the number of new elements per interval separately for target-present and target-absent trials.

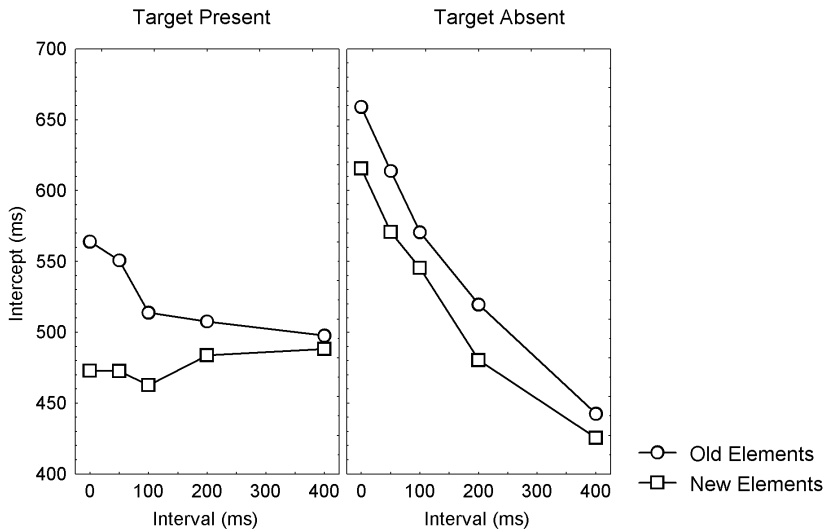


Figure 3. Mean intercepts of the functions relating RT to the number of old elements and of those relating RT to the number of new elements per interval separately for target-present and target-absent trials.

elements decreased as a function of interval, $F(4, 76) = 5.78$, $p < .01$. Separate analyses per interval for the target-present trials only revealed that the slopes of the functions relating RT to the number of old elements and those of the functions relating RT to the number of new elements differed significantly for the intervals 0 ms, $F(1, 19) = 117.69$, $p < .01$, 50 ms, $F(1, 19) = 62.70$, $p < .01$, and 100 ms, $F(1, 19) = 22.31$, $p < .01$. The slopes were not different for the intervals of 200 ms, $F(1, 19) = 3.91$, $p > .05$, and 400 ms, $F(1, 19) = 0.47$.

The intercepts of the functions were larger for target-absent trials than for target-present trials, $F(1, 19) = 15.89$, $p < .01$. An analysis was performed on the intercepts of the functions with the variables Function (the function relating RT to the number of old elements and the function relating RT to the number of new elements) and interval (0 ms, 50 ms, 100 ms, 200 ms, and 400 ms) for the target-present trials only. The intercepts of the functions relating RT to the number of old elements were larger than those of the functions relating RT to the number of new elements, $F(1, 19) = 80.65$, $p < .01$. Intercepts decreased with interval, $F(4, 76) = 2.83$, $p < .03$, and the difference between the intercepts of the functions relating RT to the number of old elements and those of the functions relating RT to the number of new elements decreased as interval increased, $F(4, 76) = 10.71$, $p < .01$.

Table 1 shows the mean percentages of errors. Overall, participants made 4.93% errors. Participants more often falsely reported the target to be absent

TABLE 1
Mean percentages of errors

		<i>Number of old elements</i>								
		<i>6</i>			<i>10</i>			<i>14</i>		
		<i>Number of new elements</i>			<i>Number of new elements</i>			<i>Number of new elements</i>		
		<i>6</i>	<i>10</i>	<i>14</i>	<i>6</i>	<i>10</i>	<i>14</i>	<i>6</i>	<i>10</i>	<i>14</i>
0 ms										
	Target present	3.0	5.5	5.3	5.3	4.0	10.0	4.3	5.5	14.3
	Target absent	1.5	2.5	3.3	2.5	2.0	2.8	2.5	2.5	1.8
50 ms										
	Target present	2.0	3.5	7.5	3.0	4.5	7.5	2.8	4.5	8.5
	Target absent	1.5	1.5	2.0	1.8	1.8	2.3	1.8	3.0	3.0
100 ms										
	Target present	2.5	4.0	7.3	2.5	6.8	6.3	4.3	6.3	5.8
	Target absent	0.5	1.3	1.8	1.8	3.5	2.0	2.5	2.3	1.0
200 ms										
	Target present	4.5	8.3	9.3	6.3	8.5	7.0	6.8	6.8	9.3
	Target absent	1.0	1.3	1.5	1.0	0.5	2.0	0.5	1.8	1.0
400 ms										
	Target present	13.8	16.3	14.8	21.5	17.8	16.8	16.5	18.5	17.5
	Target absent	1.8	0.8	1.5	1.3	0.5	0.8	1.5	1.0	2.0

when in fact the target was present than the target to be present when in fact the target was absent, $F(1, 19) = 104.08$, $p < .01$, showing that participants were more inclined to respond target absent than target present. Error rates increased with interval, $F(4, 76) = 13.58$, $p < .05$. Furthermore, error rates were either unaffected or affected in the same direction as RT.

DISCUSSION

The results of the present study demonstrate that the extent to which observers can prioritize new over old elements for selection is critically dependent on the interval between the presentation of the new elements and the target. Observers prioritize the selection of new over old elements as long as the interval between the presentation of the new elements and the target is shorter than 200 ms. After 200 ms, new elements are no longer prioritized over old elements as evident from the finding that the number of old elements and the number of new elements affected search equally at 200 ms and 400 ms. In fact, beyond 200 ms, search efficiency was significantly affected by the number of old elements

showing that observers were no longer able to ignore the presence of the old elements.

The present results are consistent with the onset account of Donk and Theeuwes (2001). Possibly, the onsets accompanying the presentation of the new elements generate an initial high level of bottom-up activation followed by a rapid decline in activation. Accordingly, as time passes, old and new elements become increasingly more equivalent in their ability to attain access to the limited attentional system. As a consequence, increasingly more old elements are selected for attention as interval increases. Old elements start to "leak through" the attentional selection mechanism with the result that the size of the preview effect diminishes as a function of interval. In fact, the finding that the effect of the number of old elements increases as the number of new elements increases is also in line with this idea. As the number of new elements increases, RT becomes larger. As a consequence, the onset signal of the new elements fades away with the result that the new elements become increasingly more equivalent to the old elements.

The present results bear much resemblance to those obtained with peripheral cues (e.g., Müller & Findlay, 1988; Müller & Rabbitt, 1989). A typical peripheral cue involuntarily attracts attention to its location by virtue of the abrupt luminance change accompanying its appearance. Previous studies have demonstrated that peripheral cues have their strongest effects on responses to targets when the cue target interval is below 200 ms. That is, the facilitory effects of peripheral cues are transient and last about 200 ms (Müller & Findlay, 1988; Müller & Rabbitt, 1989). Recently, Wright and Richard (2003) demonstrated that multiple peripheral cues also are able to generate cueing effects. They suggested that the facilitory effects of the multiple cues derive from some preattentive sensory process that occurs in parallel across the visual field on those locations where a luminance change occurred. In particular, with multiple onset cues, activity is assumed to be enhanced at each cued location within some sort of low visual representation. As a consequence, those locations, may receive prioritized selection for attentional processing. Nevertheless, activity enhancement at the cued locations is transient in nature. As a consequence, shortly after the presentation of luminance onset cues, cueing benefits disappear. The present results are completely in line with this idea.

The present findings are not necessarily in conflict with the top-down notions of the preview benefit. Even though both the visual marking notion as well as the temporal segregation notion emphasize the active top-down role of the observer in prioritized selection, it is very well possible that observers become less capable to prioritize selection of new elements as the interval between the presentation of the new elements and the target increases. Indeed, according to the visual marking account new elements are prioritized because old elements are inhibited. Possibly, this inhibition becomes less strong if new elements are presented. That is, it is possible that if new elements are presented, observers allocate some resources to those elements with the results that the inhibitory tags

associated with the old elements become less strong. As a result, the inhibition of the old elements becomes less efficient as the interval between the presentation of the new elements and the target increases.³

A temporal segregation notion can also account for the present result. Indeed, recently, Jiang and Wang (2004) also found evidence for transience in prioritized selection and concluded that the memory trace for asynchrony rapidly decays allowing prioritized selection to occur only during a limited period of time. They did not vary the interval between the presentation of the new elements and the presentation of the target. Instead, they used an accuracy paradigm that enabled them to infer the sort of memory processes underlying prioritized selection. On the basis of their results, Jiang and Wang concluded that search can only be restricted to the new items during a limited period of time after the presentation of the new items. According to Jiang and Wang, the appearance of the new elements leads to a memory trace for asynchrony that rapidly decays preventing new elements to be perfectly prioritized afterwards. To account for their results, they postulated that apart from a transient fast-decaying memory for asynchrony, a few new elements may gain access to a visual slow-decaying short-term memory that is, however, severely limited in capacity, i.e., the estimated number of elements that can be retained in this capacity appears to be less than four.

The results in the present study show that the effect of the number of old elements increases as the interval between the presentation of the new elements and the target becomes larger. It is peculiar to note that simultaneously the effect of the number of new elements decreases. One possible explanation for this finding would be that with larger intervals observers increasingly rely on the operation of some feature-based selection mechanism to segregate the relevant from irrelevant elements (Braithwaite & Humphreys, 2003; Braithwaite et al., 2003). Indeed, Braithwaite and Humphreys (2003; see also Braithwaite, et al., 2003) demonstrated that the preview benefit is modulated by the colours of the elements in the preview and search display. Their results suggested that feature grouping plays an important role in preview search. Possibly, feature grouping is slow acting with the results that its role becomes more pronounced at longer intervals. As a result, at longer intervals, the effect of the number of new elements may decrease due to the selection of some subset within the group of new elements.⁴

³ This possibility was suggested by one of the reviewers.

⁴ Apart for the possible impact of colour grouping, it is also possible that the diminishing impact of the number of new elements with interval was caused by a speed-accuracy tradeoff. Generally, with increasing interval, participants more often reported the target to be absent while it was present. This suggests that as time passes, observers are more inclined to end their search process prior to all elements being inspected. As a result, potential effects of number of elements diminish as interval increases. In view of this it is feasible to assume that the effects of the number of both old and new elements are progressively underestimated as interval increases.

The present experiment was conducted to study the time course of the preview effect after the presentation of the new elements. The results showed that beyond 200 ms, new elements are no longer prioritized for selection over old ones. This finding strongly suggests that prioritized selection of new elements is based on a transient mechanism. New elements can only be new during a limited period of time.

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